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Title:

Method for manufacturing outlet nozzles for rocket engines

TECHNICAL FIELD

The present invention relates to a method for manufacturing outlet nozzles for use in rocket engines, according to the preamble of the subsequent claim 1.

BACKGROUND OF THE INVENTION

During operation, a rocket nozzle is subjected to very high stresses, for example in the form of a very high temperature on its inside (in the order of magnitude of 800 °K) and a very low temperature on its outside (in the order of magnitude of 50 °K). As a result of this high thermal load, stringent requirements are placed upon the choice of material, design and manufacture of the outlet nozzle. At least there is a need for effective cooling of the outlet nozzle.

Cooling is normally provided by attaching individual lengths of tubing on the inside surface of the nozzle. The geometry of each tube is such that it must conform to the conical or parabolic shape of the nozzle. Additionally, the entire inside surface of the nozzle must be covered to prevent "hot spots" which could result in premature failure of the nozzle. Each nozzle has a diameter ratio from the aft or large outlet end of the nozzle to the forward or small inlet end of the nozzle. Typical diameter ratios range from 2:1 to 3:1.

According to a previously known method of manufacturing a cooled outlet nozzle, rectangular tubes of constant cross section made from nickel-based steel or stainless steel are used, which tubes are arranged parallel with another and are welded together. The tubes are helically wound such that they form an angle of helix in relation to the longitudinal axis of the nozzle, which angle increases progressively from the inlet end of the nozzle to its outlet end to form a bell shaped nozzle wall. The rocket engine exhausts flowing along the inside surface of such nozzle having helically arranged tubes result in an angled reaction force creating a roll momentum on the rocket that has to be compensated for by some additional means. These additional means often lead to increased weight and increased flow resistance. Moreover, the spiral winding means that the cooling ducts are long and hence give rise to an increased pressure drop in the flow of cooling medium.

A further method for manufacturing a rocket nozzle is described in patent document WO 00/20749. According to this method, an outer wall is positioned around an inner wall, a plurality of distancing elements are positioned between the inner wall and the outer wall. Finally, the distancing elements are joined to the walls. The distancing elements may also be integrated with the inner wall, e.g. by means of milling the inner wall. In this manner, the cooling channels may be parallel to the longitudinal axis of the nozzle. With this method, it is difficult to vary the cross sectional area of the cooling channels in the longitudinal direction, to obtain the desired diameter ratio. To overcome this, the nozzle must be built in several sections in the axial direction.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved method for manufacturing a cooled outlet nozzle for a rocket engine.

This is achieved by means of the method according to the invention, which is characterized in the steps of providing a plurality of preprocessed profile members, each having a web and flanges in opposite directions from said web, milling each profile member to present a longitudinally gradually tapering width, curving the member to conform with the wall section of the nozzle, and joining the members by welding the flanges to form a bell-shaped nozzle structure with cooling channels formed by adjacent webs and adjacent pairs of flanges.

As a result of the invention, a rocket engine nozzle may be manufactured which presents high pressure capacity, a low coolant pressure drop, a long cyclic life as well as advantageous area ratio.

Advantageous embodiments of the invention can be derived from the subsequent contingent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in the following, in a non-limiting way with reference to the accompanying drawings in which:

FIG 1 is a side view showing a nozzle according to the invention,

FIG 2 is a partial sectional view along the line A-A in Fig. 1, showing two cooling channels at the inlet

end of the nozzl , according to a first embodiment of the invention,

FIG 3 is a similar view as Fig. 2, showing the cooling channels along the line B-B at the outlet end of the nozzle,

FIG 4 is a partial sectional view along the line A-A in Fig. 1, showing two cooling channels at the inlet end of the nozzle, according to a second embodiment of the invention, and

FIG 5 is a similar view as Fig. 4, showing the cooling channels along the line B-B at the outlet end of the nozzle.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a diagrammatic and somewhat simplified side view of an outlet nozzle 10 that is produced according to the present invention. The nozzle is intended for use in rocket engines of the type using liquid fuel, for example liquid hydrogen. The working of such a rocket engine is previously known per se and is therefore not described in detail here. The nozzle 10 is cooled with the aid of a cooling medium that is preferably also used as fuel in the particular rocket engine. The invention is however not limited to outlet nozzles of this type but can also be used in those cases in which the cooling medium is dumped after it has been used for cooling.

The outlet nozzle is manufactured with an outer shape that is substantially bell-shaped. Thus, the nozzle 10 forms a body of revolution having an axis of revolution and a cross section that varies in diameter along said axis.

The nozzle wall is a structure comprising a plurality of mutually adjacent, tubular cooling channels 11 extending substantially in parallel to the longitudinal axis of the nozzle from the inlet end 12 of the nozzle to its outlet end 13. The structure is built up by profile members 14 having a varying cross section. The profile members are oriented axially along the nozzle wall and curved in the longitudinal direction to conform to the nozzle contour.

The cooling channels in the embodiment according to Fig. 2 and 3 are constructed by joining H-shaped, preprocessed profile members 14. Each profile blank has a web 15 and two pairs of flanges 16 in opposite transverse directions from said web 13. These profile blanks are milled to have a longitudinally tapering cross section and width. For this purpose, the web 15 can be machined to have a longitudinally tapering thickness in the direction of the inlet end 12. Also, the flanges 16 can be machined to confirm to the difference in diameter between the inlet 12 and outlet 13. This design makes it possible to use materials with high conductivity as copper and aluminum.

After bending the profiles to the suitable curvature, they are joined by but welds either by fusion welding or friction welding to form the nozzle wall. The but welds connect the flanges 16 of adjacent profile members 14 both at inside and outside of the nozzle wall. In these areas of the profiles, the bending stresses are considerably reduced compared to the transitions between the flanges and the adjacent web.

It is also possible to build the structure described above from the common materials for rocket engine nozzle tubes

such as stainless steel and nickel based alloys. Howev r, by using material with high thermal conductivity, large area ratios may be obtained. The low density of aluminum allows for a thick web between the channels, without resulting in excessive weight. The high conductivity in the material reduces the material temperature and at the same time the heat transferred from the flame to the cooling medium is increased. The increased heat transfer is beneficial to the expander cycle of the rocket engine. For the aluminum nozzle, the increase in heat transfer compared to stainless steel nozzle is in the order of 10%.

Fig. 4 and 5 show a second embodiment of the invention, in which each profile blank is provided with two flanges 16 on one side of the web 15 and a single flange 16 on the opposite side of the web. As in the previously described embodiment, the flanges 16 can be machined to present the desired longitudinally tapering section. As the profile blanks are not symmetrical, it is necessary in the machining process to make both left and right hand versions of the profile members. The weld 17 is accessible from the outside permitting assembly welding from the outside.

The profile members 14 are joined by fusion or solid state welding, e.g. friction welding so that the parallel pairs of flanges in two adjacent members form a cooling channel 14. The single flange in the pair of members of the next following joint is joined as in Fig. 5. With this configuration, the welding of a pair of left and right profile members to form the cooling channel can be made before the actual welding to form the nozzle. Thus, the cooling channel welds are accessible from both sides.

Subsequently, the pairs of profile members are join d to form the nozzle, preferably by welding from the outside of the nozzle.

In the embodiment according to Fig. 4 and 5, the wet surface, i.e. the surface in contact with the rocket flame during operation, is increased to enhance the heat transfer to the cooling medium. Also, the inner wall is not continuous which minimizes the thermal stresses in the tangential direction. The increased wet surface according to this embodiment, cools the boundary layer more than at a conventional nozzle. The boundary layer leaving the rocket nozzle will be cooler. The cooler boundary layer serves as cooling film for an eventual non cooled nozzle extension that may be used as a low cost solution when the heat load is limited.

As an alternative to the above described manufacturing methods, the profile members 14 may be preprocessed by roll forming sheet metal plate. This sheet metal plate may for example comprise stainless steel and nickel base material.

The manufacturing concept according to the invention allows for building large nozzles with large expansion ratios. It also enables wide cross sections of the cooling channels as the area ratio is increasing. Wide channels limit the pressure capacity in the cooling channels. The large distance in between cooling channels increases the area ratio without increasing the cross section of the cooling channels.

A secondary advantag of the inventi n is the arrangement of the cooling channels offering a large cooling surface. The cooling channels do not have to cover the entire circumference. This means that the maximum diameter becomes smaller. The pressure capacity benefits from the smaller diameter.

The rotational symmetric surface of the proposed nozzle provides stiffness in itself, and allows for easy attachment of stiffeners, when needed. The cross section of the cooling channels may be close to circular. This means that the temperature differences and associated stresses are lower than compared to nozzle walls, that have a continuous inner wall.

The invention is not limited to the above-described embodiments, but several modifications are possible within the scope of the following claims. For example, the joining of two sections may be performed differently than described.

C.13537, 2001-01-09

CLAIMS

1. Method for manufacturing an outlet nozzle (10) for use in a liquid fuel rocket engine, said nozzle forming a body of revolution having an axis of revolution and a cross section which varies in diameter along said axis, and having a wall structure comprising a plurality of mutually adjacent cooling channels (11), extending substantially in parallel from the inlet end (12) of the nozzle to its outlet end (13),
c h a r a c t e r i z e d in the steps of

providing a plurality of preprocessed profile members (14), each having a web (15) and flanges (16) protruding in opposite directions from said web,

milling each profile member (14) to present a longitudinally gradually tapering width,

curving said member (14) to conform with the wall section of the nozzle, and

joining the members by welding the flanges (16) to form a bell-shaped nozzle structure with cooling channels (11) formed by adjacent webs (15) and adjacent pairs of flanges (16).

2. Method according to claim 1,
c h a r a c t e r i z e d in
that each profile member (14) is provided with two flanges (16) on one side of the web (15) and one flange (16) on the opposite side of said web.

3. Method according to claim 1,
c h a r a c t e r i z e d in

that each profile member (14) is pr vid d with two flanges (16) on each side of the web (15).

4. Method according to any one of claims 1-3, c h a r a c t e r i z e d in that the profile members (14) are extruded from aluminum.

5. Method according to any one of claims 1-3, c h a r a c t e r i z e d in that the profile members (14) are extruded from copper.

6. Method according to any one of claims 1-3, c h a r a c t e r i z e d in that the profile members (14) are preprocessed by forming sheet metal plate.

7. Method according to claim 6, c h a r a c t e r i z e d in that the sheet metal plate comprises stainless steel and nickel base material.

8. Method according to any one of claims 1-7, c h a r a c t e r i z e d in milling the flanges (16) so the channel cross sectional area is larger at the outlet nozzle end (13) than at the inlet nozzle end (12).

9. Method according to claim 8, c h a r a c t e r i z e d in the additional step of milling the web (15) to present a longitudinally gradually tapering width.

10. A m thod according to any one of claims 1-9, c h a r a c t e r i z e d in that the welding is realized by means of fusion welding.

11. A method according to any one of claims 1-10, c h a r a c t e r i z e d in extruding the profile members (14) with rounded transitions between the web (15) and the flanges (16).

12. A method according to any one of claims 1-11, c h a r a c t e r i z e d in the step of welding the profile members (14) to present a rotational symmetric outer nozzle surface.

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ABSTRACT

A method for manufacturing an outlet nozzle (10) for use in a liquid fuel rocket engine. The nozzle forms a body of revolution having an axis (11) of revolution and a cross section that varies in diameter along said axis. The nozzle has a wall structure comprising a plurality of mutually adjacent cooling channels extending substantially in parallel from the inlet end (13) of the nozzle to its outlet end (14). The method of manufacturing comprises the step of providing a plurality of preprocessed profile members (14), each having a web (15) and flanges (16) in opposite directions from said web. Each profile member (14) is machined to present a longitudinally gradually tapering width. The member is curved to conform with the wall section of the nozzle, and members are joined by welding the flanges (16) to form a bell-shaped nozzle structure with cooling channels (11) formed by adjacent webs (15) and adjacent pairs of flanges (16).

(Fig. 3)

Fig.1

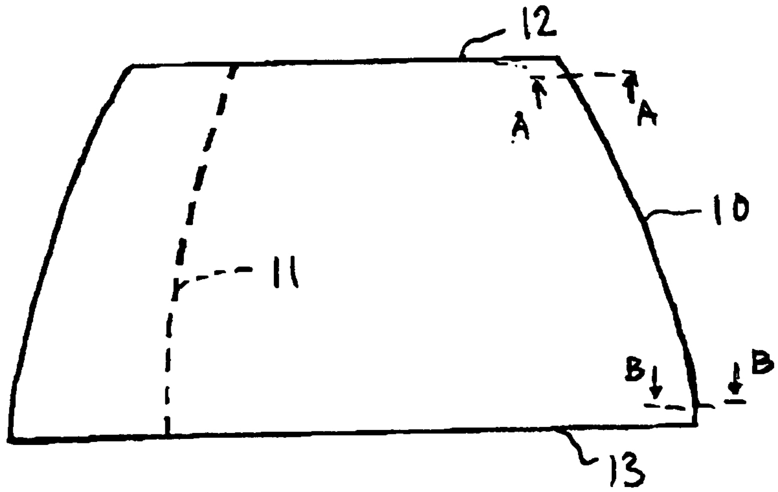

Fig. 2

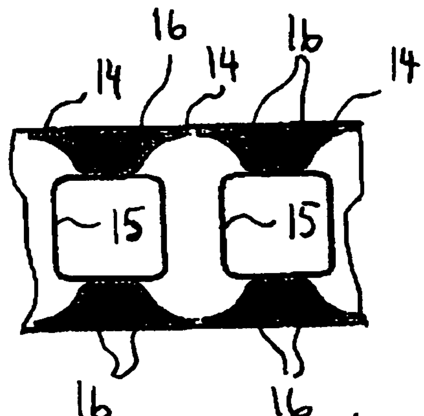

Fig.3

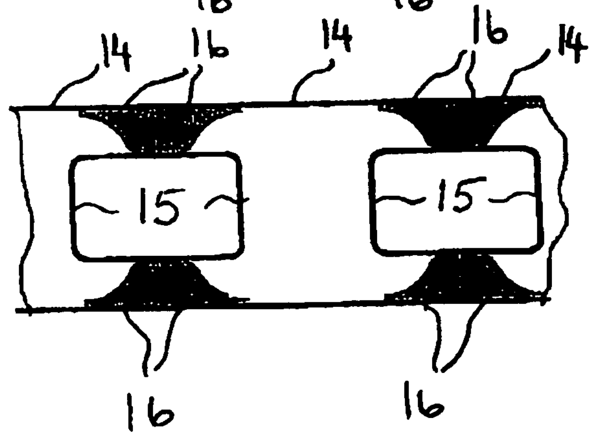

Fig. 4

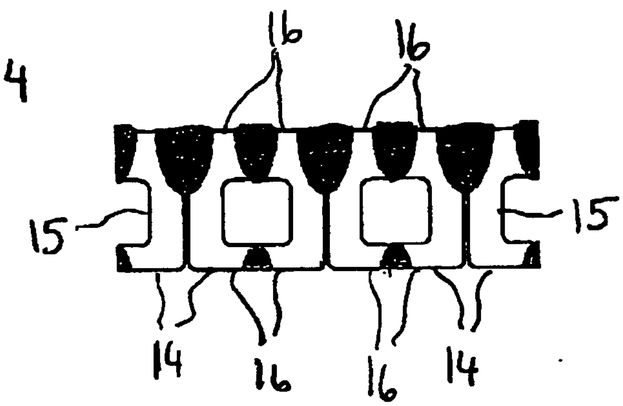

Fig. 5